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Volume and Asymmetry of the Pulvinar Thalami in Patients Diagnosed with Migraine*

Migren Tanısı Almış Olan Hastalarda Pulvinar Thalami Hacmi ve Asimetrisi

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Objective: The pulvinar thalami is one of the important thalamic nuclei associated with visual processing and multisensory integration. Alterations in thalamo-visual connections related to photophobia and sensory hypersensitivity have been reported in patients with migraine. In this study, it was aimed to compare the right and left pulvinar thalami volumes and the asymmetry between these structures in female patients diagnosed with migraine and healthy individuals.
Materials and Methods: The study included 40 female patients with migraine, aged 20–49 years, and 30 healthy female individuals, aged 22–47 years, who underwent cranial magnetic resonance imaging at Balıkesir University Training and Research Hospital between 2023 and 2024. Cranial MR images were transferred to the VolBrain software, and the total, right, and left volumes of the pulvinar thalami as well as asymmetry values were morphometrically evaluated. Statistical analyses were performed using SPSS 25 software. Independent Samples T-Test was used for intergroup comparisons, while Pearson correlation analysis was used to evaluate the relationships with age.
Results: No significant difference was found between patients diagnosed with migraine and healthy individuals in terms of total, right, and left pulvinar thalami volumes ($p>0.05$). However, a significant negative correlation was found between pulvinar thalami asymmetry index values and age in the migraine group ($r=-0.333$; $p=0.036$). No significant correlation was detected in the control group.
Conclusion: Although no significant morphometric alterations were detected in pulvinar thalami volumes in migraine patients, pulvinar asymmetry showed a significant negative correlation with age in the migraine group. Considering the central role of the pulvinar thalami within the thalamo-visual system, it is thought that functional connectivity alterations rather than structural changes may play a more prominent role in migraine pathogenesis.
Keywords: Migraine, Pulvinar Thalami, Thalamus, Asymmetry, Morphometry

Amaç: Pulvinar thalami, talamusun görsel işlemleme ve multisensoriyel entegrasyon ile ilişkili önemli çekirdeklerinden biridir. Migren hastalarında özellikle fotofobi ve duyusal hassasiyet ile ilişkili talamo-vizüel bağlantılarda değişiklikler olduğu bildirilmektedir. Bu çalışmada migren tanısı almış olan kadın hastalarda sağ ve sol pulvinar thalami hacimleri ile bu yapılar arasındaki asimetrinin sağlıklı bireylerle karşılaştırılması amaçlandı.
Gereç ve Yöntem: Çalışmaya Balıkesir Üniversitesi Eğitim ve Araştırma Hastanesi'nde 2023-2024 yılları arasında kranial manyetik rezonans görüntülemesi bulunan 20-49 yaş aralığında 40 kadın migren hastası ile 22-47 yaş aralığında 30 sağlıklı kadın birey dahil edildi. Kranial MR görüntüleri VolBrain yazılımına aktarılarak pulvinar thalami'nin total hacmi, sağ ve sol hacimleri ile asimetri değerleri morfometrik olarak değerlendirildi. İstatistiksel analizler SPSS 25 programı kullanılarak gerçekleştirildi. Gruplar arası karşılaştırmalarda Bağımsız Grup T-Testi, yaş ile ilişkilerin değerlendirilmesinde Pearson korelasyon analizi kullanıldı.
Bulgular: Migren tanısı almış olan hastalar ile sağlıklı bireyler arasında total, sağ ve sol pulvinar thalami hacimleri açısından anlamlı farklılık saptanmadı ($p>0,05$). Bununla birlikte migren grubunda pulvinar thalami asimetri indeks değerleri ile yaş arasında negatif yönde anlamlı korelasyon bulundu ($r=-0,333$; $p=0,036$). Kontrol grubunda ise anlamlı korelasyon saptanmadı.
Sonuç: Migren hastalarında pulvinar thalami hacimlerinde belirgin morfometrik değişiklik saptanmamış olsa da migren grubunda pulvinar asimetrisi ile yaş arasında anlamlı negatif korelasyon saptanmıştır. Pulvinar thalami'nin talamo-vizüel sistem içerisindeki merkezi rolü göz önünde bulundurulduğunda, migren patogenezinde yapısal değişikliklerden çok fonksiyonel bağlantı değişikliklerinin ön planda olabileceği düşünülmektedir.
Anahtar Kelimeler: Migren, Pulvinar Thalami, Thalamus, Asimetri, Morfometri

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INTRODUCTION

Migraine is a complex neurological disorder of neurovascular origin characterized by recurrent headache attacks (Hu et al., 2015). In addition to headache, it may be accompanied by numerous neurological symptoms such as photophobia, phonophobia, osmophobia, and various sensory hypersensitivities (Schwedt et al., 2013). Recent neuroimaging studies have demonstrated that migraine is not solely a vascular disease but also a neurobiological disorder affecting both cortical and subcortical networks.

The thalamus functions as one of the principal relay structures responsible for conveying sensory information to the cerebral cortex (Brennan, 2018). In particular, the posterior thalamus and the pulvinar thalami are structures of interest in migraine pathophysiology due to their extensive connections with the visual system. The pulvinar thalami plays an important role in multisensory integration through its widespread connections with the visual cortex, precuneus, auditory cortex, and somatosensory areas (Tu et al., 2019; Brennan, 2018). Therefore, the pulvinar thalami is thought to be involved in the photophobia and sensory hypersensitivity observed during migraine attacks.

Maleki et al. (2012) demonstrated direct connections between the optic nerve and the pulvinar and suggested that this pathway may play a role in the development of light-induced pain during migraine attacks. Similarly, Tu et al. (2019) reported alterations in the dynamic functional connectivity between the pulvinar thalami and the visual cortex in patients with migraine. The association of the pulvinar with migraine headache frequency suggests that this structure may represent an important hub in the sensory symptoms of migraine.

The involvement of the thalamus in migraine pathophysiology extends beyond functional connectivity mechanisms. Previous studies have also described volumetric alterations affecting specific thalamic nuclei in migraine patients. Shin et al. (2019) reported enlarged medial geniculate nucleus volumes together with reduced parafascicular nucleus volumes in individuals diagnosed with migraine. However, some studies have reported no significant differences in total thalamic volume or pulvinar volume. Although microstructural alterations of the thalamus have been reported particularly in patients with migraine with aura, the results of volumetric evaluations remain inconclusive in the literature.

Since photophobia and multisensory hypersensitivity observed during migraine attacks are associated with the thalamo-visual system, investigating the structural characteristics of the pulvinar thalami is of particular importance. In this study, right and left pulvinar thalami volumes and the asymmetry between these structures were evaluated in female patients diagnosed with migraine and compared with healthy individuals.

MATERIALS AND METHODS

Study Design

This study was designed as a retrospective cross-sectional observational investigation conducted at Balıkesir University Health Practice and Research Hospital. Cranial magnetic resonance images together with associated clinical information were retrospectively collected from the hospital archive database for evaluation.

Ethical Approval

Approval for the study was granted by the Non-Interventional Clinical Research Ethics Committee of Balıkesir University Faculty of Medicine (Decision No: 2025/10-10; Date: 18/11/2025). All procedures were carried out in accordance with the ethical standards of the Declaration of Helsinki. Since the study was based on retrospectively collected data, informed consent from participants was not required.

Study Population

The study population consisted of 40 female patients between the ages of 20 and 49 years who had been diagnosed with migraine and 30 age-matched healthy female controls between 22 and 47 years of age. Migraine is known to occur more frequently in women than in men, with prevalence rates reported to be approximately two to four times higher in females, particularly after puberty. Therefore, only female participants were included in the present study to obtain a more homogeneous study population and to minimize sex-related variability (Rossi et al., 2022). Retrospective evaluation of T1-weighted cranial magnetic resonance images was performed for all participants. The mean age was 33.28 ± 8.04 years in the migraine group and 32.67 ± 7.16 years in the control group. Migraine diagnoses were established by a neurologist based on the International Classification of Headache Disorders-3 (ICHD-3) criteria.

Inclusion Criteria

Individuals meeting the following criteria were included in the study:
•Female individuals aged 18 years and older,
•Having a diagnosis of episodic migraine with or without aura confirmed according to ICHD-3 criteria,
•Having at least a one-year history of migraine in clinical records,
•Having artifact-free T1-weighted MR images of adequate quality for evaluation.

Exclusion Criteria

Individuals with the following characteristics were excluded from the study:
•History of epilepsy, stroke, demyelinating disease, or intracranial tumor,
•Diagnosis of psychiatric disease,
•History of severe head trauma,
•Presence of contraindications preventing magnetic resonance imaging,
•Inadequate image quality for volumetric evaluation,
•Diagnosis of medication overuse headache (MOH).
In addition, individuals in the control group had no history of headache, regular medication use, or known chronic disease.

MR Imaging Protocol

Cranial MR images of the participants were obtained using a Philips Ingenia 1.5 Tesla magnetic resonance imaging device located at Balıkesir University Health Practice and Research Hospital. The images were anonymized from the hospital PACS (Picture Archiving and Communication System) archive and evaluated in DICOM format.

MR examinations were performed using a three-dimensional T1-weighted multiplanar turbo spin echo (3D T1-MPTSE) sequence obtained in the sagittal plane. Imaging parameters were approximately as follows: 1×1×1 mm voxel size, 1–1.1 mm slice thickness, 0 mm slice gap, 7.0 ms repetition time (TR), 3.4 ms echo time (TE), 256×240 mm field of view (FOV), and 256×216 matrix size. All images were independently evaluated by two researchers in terms of anatomical integrity and motion artifacts.

Volumetric Analysis

T1-weighted structural MR images of the participants were uploaded to the VolBrain (www.volbrain.upv.es) platform for the evaluation of pulvinar thalami volumes. The VolBrain system automatically calculates right and left pulvinar thalami volumes in cubic centimeters (cm^3) using an automatic segmentation method based on high-resolution T1-weighted images.

For each participant, right pulvinar thalami volume, left pulvinar thalami volume, and total pulvinar thalami volume were obtained. Asymmetry index values automatically generated by the VolBrain platform during the automated segmentation process were also recorded and included in the statistical analyses. Therefore, no separate manual asymmetry calculation was performed by the researchers. The obtained volumetric data were used to investigate possible morphological differences between the migraine and control groups.

Statistical Analysis

Statistical processing of the data was carried out using IBM SPSS Statistics Version 25.0. Prior to the main analyses, data distribution patterns were evaluated with the Kolmogorov–Smirnov test. Since the variables showed normal distribution characteristics, parametric statistical approaches were preferred. Intergroup comparisons for total, right, and left pulvinar thalami volumes as well as asymmetry index values were performed with the independent samples t-test. Relationships between age and pulvinar thalami measurements were analyzed separately in each group using Pearson correlation analysis. A p value below 0.05 was accepted as statistically significant. Quantitative data were reported as mean ± standard deviation (SD).

RESULTS

In this study, cranial magnetic resonance images of 40 female patients diagnosed with migraine and 30 healthy female individuals were retrospectively evaluated at Balıkesir University Health Practice and Research Hospital between 2023 and 2024.

Distribution patterns of the study data were assessed with the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. Since the sample size in the study was greater than 30, the Kolmogorov–Smirnov test was taken as the basis for the normality assessment. According to the Kolmogorov–Smirnov test results, only the age variable in the migraine group did not show normal distribution ($p = 0.006$). However, the skewness and kurtosis values of all variables, including age, were found to be between −1.5 and +1.5. According to Tabachnick and Fidell (2013), values within this range are considered acceptable limits for normal distribution. Therefore, all data in the study were accepted as normally distributed, and parametric analysis methods were used. The normality test results of the groups are presented in Table 1.

Table 1. Normality Test Results of the Groups (control groups n=30, migraine groups n=40)

Parameters	Groups	p	Skewness	Kurtosis
Age	Control	0.200	0.371	-0.859
	Migraine	**0.006**	0.380	-0.910
Total Pulvinar Thalami (cm³)	Control	0.200	0.223	-0.849
	Migraine	0.200	0.234	-0.694
Right Pulvinar Thalami (cm³)	Control	0.200	0,317	-0.630
	Migraine	0.200	0.056	-0.456
Left Pulvinar Thalami (cm³)	Control	0.084	0.254	-1.046
	Migraine	0.200	0.245	-0.453
Pulvinar Thalami Asymmetry (%)	Control	0.200	-0.150	0.579
	Migraine	0.066	-0.006	-1.147

p: significance, **cm³:** cubic centimeter, **%:** percentage

Comparisons of total, right, and left pulvinar thalami volumes together with pulvinar asymmetry index values between the migraine and control groups were performed using the independent samples t-test.

Statistical evaluation demonstrated no significant intergroup differences for any of the examined parameters ($p > 0.05$). Group- based volumetric findings and corresponding t-test results are summarized in Table 2.

Table 2. Comparison of Pulvinar Thalami Volumes Between Migraine and Control Groups Using Independent Samples t-Test

Parameters	Control (x̄±SD) (n=30)	Migraine (x̄±SD) (n=40)	Cohen's d	95% CI for Cohen's d	p
Age	32.67 ± 7.16	33.28 ± 8.04	0.079	−0.394 to 0.553	0.744
Total Pulvinar Thalami (cm³)	2.30 ± 0.22	2.33 ± 0.22	0.127	−0.347 to 0.601	0.600
Right Pulvinar Thalami (cm³)	1.13 ± 0.11	1.13 ± 0.11	0.035	−0.438 to 0.508	0.885
Left Pulvinar Thalami (cm³)	1.17 ± 0.12	1.19 ± 0.12	0.179	−0.295 to 0.653	0.461
Pulvinar Thalami Asymmetry (%)	−3.61 ± 6.30	−5.14 ± 7.80	-0.213	−0.688 to 0.261	0.366

p: significance, **cm³:** cubic centimeter, **%:** percentage, **x̄±SD:** mean ± standard deviation, **CI:** confidence interval

Pearson correlation analysis was performed separately for the migraine and control groups to evaluate the relationships between age and pulvinar thalami parameters. In the migraine group, a statistically significant negative correlation was found between age and pulvinar thalami asymmetry index values ($r = -0.333$, $p = 0.036$). No significant relationship was observed between age and total, right, or left pulvinar thalami volumes ($p > 0.05$). In the control group, no statistically significant correlation was detected between age and pulvinar thalami volumes or asymmetry index values ($p > 0.05$). Correlation analysis results are presented separately in Table 3 and Table 4.

Table 3. Pearson Correlation Analysis Results for the Migraine Group (n = 40)

Parameters	Age	Total Pulvinar Thalami	Right Pulvinar Thalami	Left Pulvinar Thalami	Asymmetry Index
Age	—	r = -0.065 p = 0.690	r = -0.204 p = 0.207	r = 0.074 p = 0.649	r = -0.333 p = 0.036*
Total Pulvinar Thalami (cm³)	r = -0.065 p = 0.690	—	r = 0.919 p < 0.001*	r = 0.935 p < 0.001*	r = -0.106 p = 0.516
Right Pulvinar Thalami (cm³)	r = -0.204 p = 0.207	r = 0.919 p < 0.001*	—	r = 0.720 p < 0.001*	r = 0.293 p = 0.067
Left Pulvinar Thalami (cm³)	r = 0.074 p = 0.649	r = 0.935 p < 0.001*	r = 0.720 p < 0.001*	—	r = -0.448 p = 0.004*
Asymmetry Index (%)	r = -0.333 p = 0.036*	r = -0.106 p = 0.516	r = 0.293 p = 0.067	r = -0.448 p = 0.004*	—

*** p < 0.05 was considered statistically significant.**
r: Pearson correlation, **p:** significance, **n:** sample size, **%:** percentage, **cm³:** cubic centimeter

Table 3. Pearson Correlation Analysis Results for the Control Group (n = 30)

Parameters	Age	Total Pulvinar Thalami	Right Pulvinar Thalami	Left Pulvinar Thalami	Asymmetry Index
Age	—	r = 0.006 p = 0.974	r = -0.010 p = 0.958	r = 0.029 p = 0.878	r = -0.039 p = 0.839
Total Pulvinar Thalami (cm³)	r = 0.006 p = 0.974	—	r = 0.943 p < 0.001*	r = 0.952 p < 0.001*	r = -0.054 p = 0.777
Right Pulvinar Thalami (cm³)	r = -0.010 p = 0.958	r = 0.943 p < 0.001*	—	r = 0.798 p < 0.001*	r = 0.279 p = 0.135
Left Pulvinar Thalami (cm³)	r = 0.029 p = 0.878	r = 0.952 p < 0.001*	r = 0.798 p < 0.001*	—	r = -0.354 p = 0.055
Asymmetry Index (%)	r = -0.039 p = 0.839	r = -0.054 p = 0.777	r = 0.279 p = 0.135	r = -0.354 p = 0.055	—

*** p < 0.05 was considered statistically significant.**
r: Pearson correlation, **p:** significance, **n:** sample size, **%:** percentage, **cm³:** cubic centimeter

DISCUSSION

In the present study, volumetric measurements of the pulvinar thalami were compared between female migraine patients and healthy controls. Statistical analyses demonstrated comparable total, right, and left pulvinar thalami volumes as well as asymmetry index values between the two groups. Correlation analyses further revealed strong positive associations between total pulvinar volume and bilateral pulvinar measurements. Moreover, asymmetry index values tended to increase with right pulvinar volume and decrease with left pulvinar volume.

Migraine is considered a complex neurovascular disorder that cannot be explained solely by vascular alterations and affects sensory processing, pain modulation, and thalamocortical connections (Hu et al., 2015). Symptoms such as photophobia, phonophobia, and multisensory hypersensitivity are thought to be associated with functional alterations in thalamic structures. In this context, the pulvinar thalami is one of the structures attracting attention in migraine pathophysiology due to its extensive connections with the visual system (Puledda et al., 2019).

Through its extensive connections with the visual cortex, precuneus, somatosensory regions, and association cortices, the pulvinar thalami is considered a key structure involved in multisensory integration (Brennan, 2018). Altered thalamo-visual network activity mediated by the pulvinar thalami has been proposed to contribute to visual hypersensitivity and light-related pain during migraine attacks. Maleki et al. (2012) identified direct anatomical connections between the optic nerve and the pulvinar thalami and emphasized the possible involvement of these pathways in migraine-related photophobia.

Evidence obtained from functional neuroimaging studies further highlights the involvement of the pulvinar thalami in migraine pathophysiology. Tu et al. (2019) identified abnormal dynamic functional connectivity patterns between the posterior thalamus, especially the pulvinar thalami, and the visual cortex in individuals with migraine. Likewise, Dumkrieger et al. (2019) demonstrated disruptions in thalamocortical network organization, particularly in sensory processing pathways. Collectively, these findings indicate that alterations in functional connectivity may be more relevant than structural volumetric changes in migraine pathogenesis.

The comparable pulvinar thalami volumes identified in the migraine and control groups in our study are in agreement with several previous morphometric investigations. Hougaard et al. (2020) did not identify structural thalamic abnormalities in female migraine patients. In a similar manner, Shin et al. (2019) described volumetric alterations in certain thalamic nuclei; however, they did not observe a distinct volumetric alteration involving the pulvinar thalami. The absence of volumetric differences in total, right, and left pulvinar thalami measurements in the current study may indicate that migraine-related alterations predominantly involve functional rather than structural mechanisms.

Nevertheless, there are studies in the literature reporting microstructural alterations in thalamic structures in migraine patients. Granziera et al. (2014) demonstrated microstructural alterations in the pulvinar and lateral posterior nuclei, particularly in patients with migraine with aura. However, it has been stated that these alterations may not always be detected by volumetric analyses. This finding indicates the limitations of volumetric analyses and suggests that migraine pathophysiology cannot be explained solely by morphological changes.

One of the remarkable findings of our study was the relationship between the pulvinar asymmetry index and right and left pulvinar volumes. It was observed that the asymmetry index increased with increasing right pulvinar volume, whereas it decreased with increasing left pulvinar volume. This finding suggests that structural differences associated with lateralization may be present in migraine patients. Since the asymmetry index was mathematically derived from right and left pulvinar thalami volumes, correlations involving these variables should be interpreted cautiously. In the migraine group, a statistically significant negative correlation was identified between age and pulvinar thalami asymmetry index values. This finding may suggest that age-related changes could influence pulvinar asymmetry in individuals with migraine.

The pulvinar thalami is known to be an important structure not only in sensory integration but also in pain modulation. Brennan (2018) reported that the posterolateral thalamus plays an important role particularly in the development of photophobia and allodynia. It is possible that the sensory hypersensitivity observed during migraine attacks is associated with thalamocortical network alterations organized through the pulvinar. Therefore, the pulvinar thalami should be evaluated not only morphologically but also functionally and in terms of connectivity in migraine pathophysiology.

LIMITATIONS

The findings of this study should be interpreted in light of several methodological constraints. The sample size may not have been sufficient to identify minor differences in pulvinar thalami volumes. Moreover, as the study included only female participants, the applicability of the results to male individuals remains limited.

Because of the retrospective study design, detailed clinical characteristics such as migraine duration, attack frequency, pain severity, and medication-related factors could not be comprehensively analyzed. Another limitation is that only volumetric measurements were evaluated, whereas functional interactions involving the pulvinar thalami were not investigated. Moreover, advanced neuroimaging modalities such as functional MRI and diffusion tensor imaging were not included in the study protocol.

CONCLUSION

Overall, the present findings indicate that pulvinar thalami volumes in individuals with migraine are comparable to those observed in healthy controls. Nevertheless, due to its prominent role within the thalamo-visual network, the pulvinar thalami is still considered to be a relevant structure in the pathophysiology of migraine.

Although no structural volumetric differences were detected in our study, the functional connectivity alterations reported in the literature support the importance of the pulvinar thalami in migraine pathophysiology. Therefore, future studies including larger sample sizes, prospective designs, and functional imaging methods are thought to reveal the role of the pulvinar thalami in migraine pathogenesis in greater detail.

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Conflict of Interest: The authors declare no conflict of interest.

Ethics Approval and Consent to Participate: This study was evaluated and approved by the Balıkesir University Non-Interventional Clinical Research Ethics Committee with the decision dated November 18, 2025, and numbered 2025/10-10. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Since the data were retrospectively reviewed, additional informed consent was not obtained from the participants.

Availability of Data and Materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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